p-TYPE CuO NANOWIRE PHOTODETECTORS

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Abstract

Nanowires (NWs) have a great potential as building blocks of optical sensors due to their high crystal quality and surface-to-volume ratio which typically lead to high optical gains [1,2]. Metal oxide NW based photodetectors have demonstrated response values well beyond the values achieved in mesoscopic devices. Most of these metal oxides are n-type and, despite their high optical response, present slow response transients due to the chemisorption of gas molecules (particularly oxygen) that hinder his practical operation. Up to now, p-type nanowires have been less studied. In that respect, cupric oxide (CuO) NWs are excellent candidates to analyze because of their high aspect ratio and high conductivity when they are synthesized by oxidizing copper foils. In addition, its optical bandgap (~1.4 eV) [2] lies in the infrared range allowing detection in the full visible spectrum.

One of the main issues for the integration of nanostructures in microtechnology is the reproducible assembly of those nanostructures to form a functional device [3]. Dielectrophoresis is a well-known method used to separate biomolecules which has been proved to be a low-cost approach for this aim [3,4]. Briefly, an AC electric field is used to align nanostructures between electrodes, previously defined by photolithography. Depending on several factors, such as the nanostructure conductivity, the dielectric constant of the solvent, the substrate and the experimental conditions applied, a controlled alignment occurs. One of the advantages is that no corrosive chemical products or long processes are needed.

In this work, copper (II) oxide NWs were grown by thermal oxidation of a copper foil on a heater at approximately 410 ºC during 1 hour (Figure 1, left image) and ultrasonically dispersed. They were dielectrophoretically aligned in a silicon wafer with SiO_2 thin film thermally grown, and aluminum electrodes with a 15 µm gap photolithographed by chemical etching (inset Figure 1, right image). Experimental conditions were also studied, changing the frequency, peak-to-peak voltage and electrode gap, to achieve the best alignment. The resulting nanostructures were observed by optical microscope, during the process, and by scanning electron microscope to see the contact between the nanostructure and the electrode (Figure 1, right image). The current-voltage characteristic in darkness present a slight rectifying behavior likely induced by the formation of a thin oxide layer between the aluminum electrodes and the CuO NW (Figure 2(a)). The optoelectronic response of the aligned NWs was characterized using a halogen lamp (Figure 2(b)). Below 4 V the response was almost negligible. For bias voltages higher than 4 V, the photocurrent increases significantly with bias. In addition, the rise and decay times were lower than 1 s in contrast to those found in n-type NW based photodetectors. This fast response is a promising result for their use in high-speed and high-sensitivity devices in the visible range of the electromagnetic spectrum. Further studies are being carried out to determine the actual time and spectral response.

References

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Figures

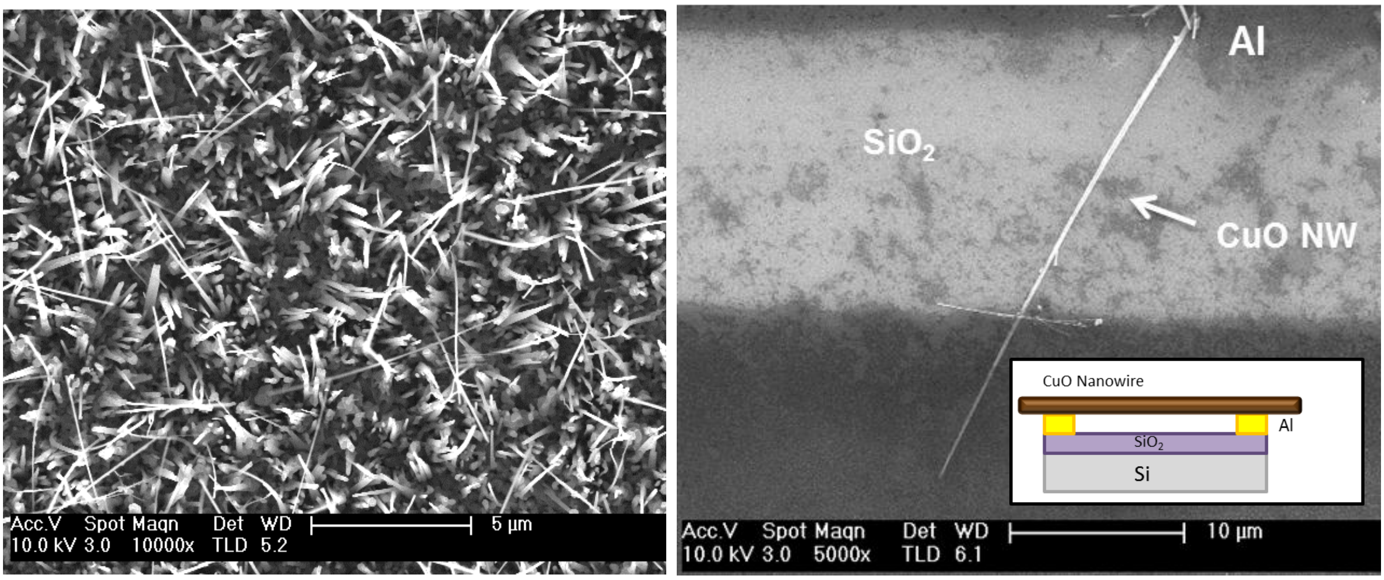

Fig. 1: Scanning electron microscope images: CuO nanowires thermally grown (left) and CuO NW dielectrophoretically aligned (right).

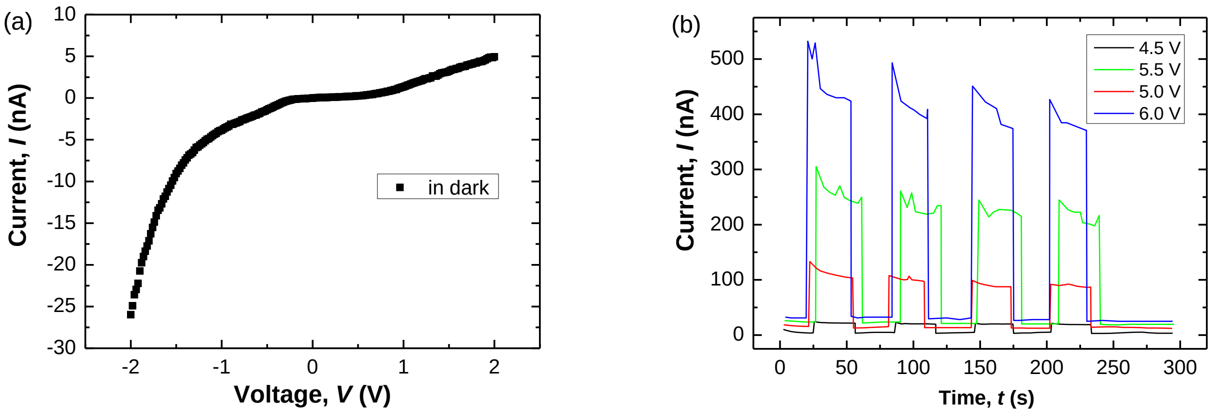

Fig. 2: Current-voltage curve for CuO NWs in dark (a) and their response to a halogen lamp (b).